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Ikai et al.

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(54) **MAGNETIC HEAD AND MAGNETIC DISK DEVICE**

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G11B 5/127	(2006.01)
G11B 5/012	(2006.01)
G11B 5/00	(2006.01)

(52) **U.S. Cl.**

CPC ***G11B 5/3136*** (2013.01); ***G11B 5/012*** (2013.01); ***G11B 5/1278*** (2013.01); ***G11B 5/255*** (2013.01); ***G11B 5/314*** (2013.01); ***G11B 5/483*** (2015.09); *G11B 2005/0021* (2013.01)

(58) **Field of Classification Search**

CPC G11B 5/012; G11B 5/3136; G11B 5/314; G11B 5/4866; G11B 2005/0021; G11B 5/6088; G11B 7/1387; G11B 11/10554; G11B 11/1058; G11B 5/3133; G11B 13/08; G11B 5/6011; G11B 5/1278; G11B 5/483; G11B 5/255; G11B 5/02

USPC 369/13.13, 13.33, 13.32, 13.01; 360/204.1, 59, 39, 125

See application file for complete search history.

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(57) **ABSTRACT**

According to one embodiment, a magnetic head is arranged opposite a magnetic recording medium including a recording layer. The magnetic head includes a magnetic pole, a light emitting unit, and a distance adjusting unit. The magnetic pole includes a soft magnetic material. The light emitting unit is arranged with respect to the magnetic pole in a travel direction of the magnetic head, and emits light with respect to the recording layer. The distance adjusting unit adjusts a distance between the magnetic pole and the light emitting unit.

18 Claims, 8 Drawing Sheets

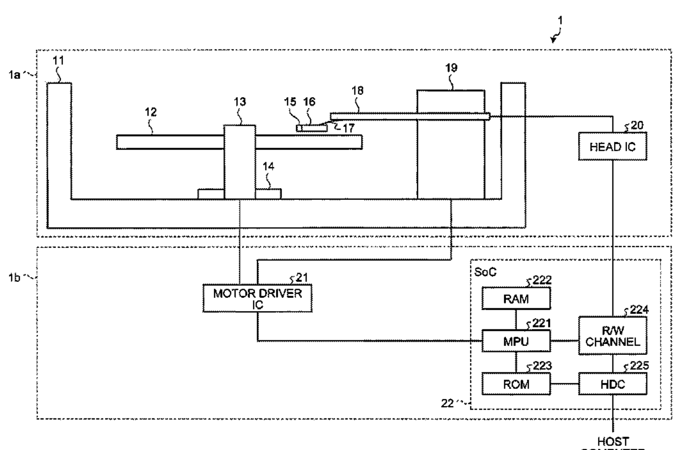


FIG.1

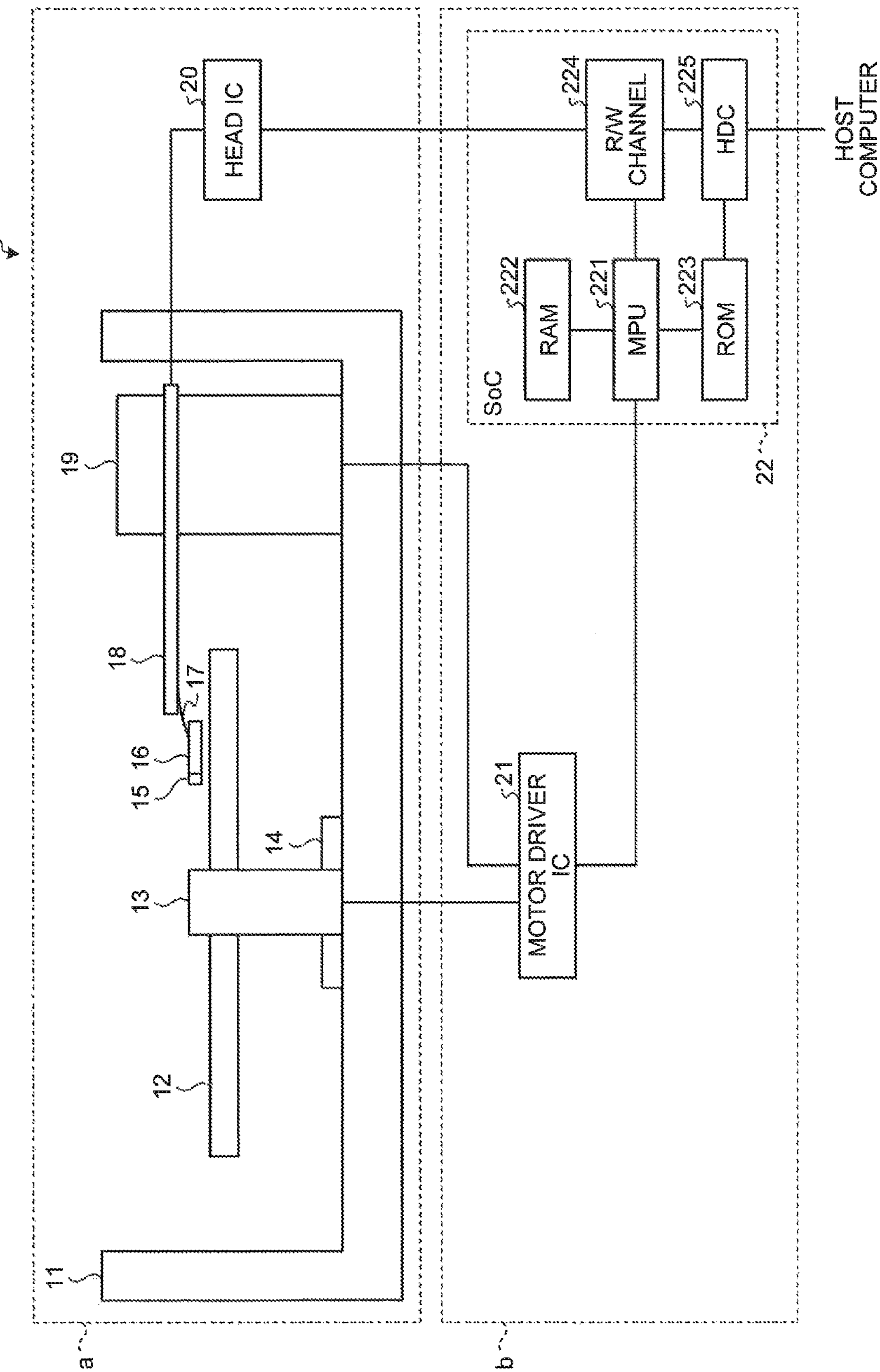
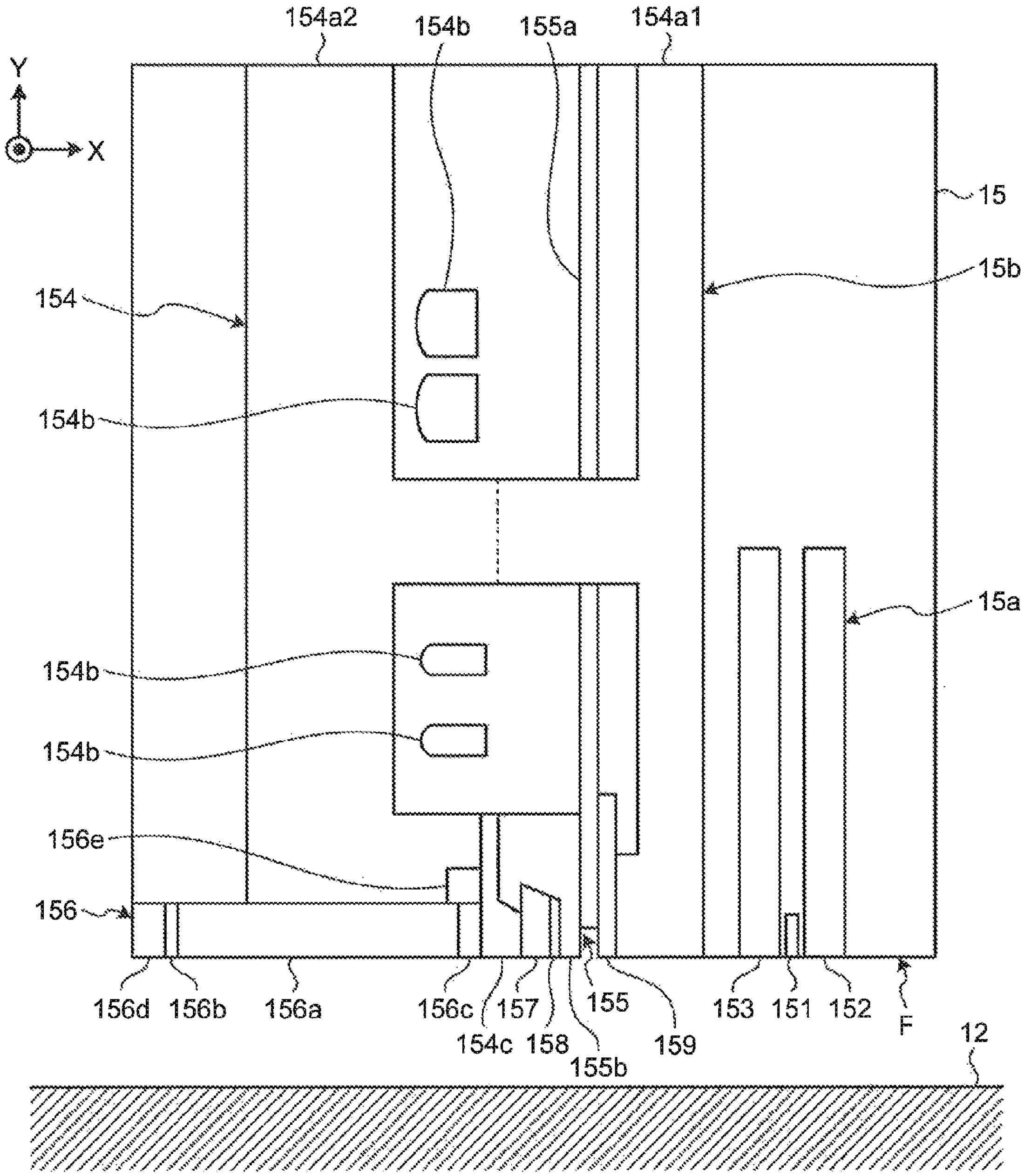

1
HEAD IC
20
R/W CHANNEL
224
HDC
225
HOST COMPUTER
RAM
222
MPU
221
ROM
223
SoC
22
19
18
17
16
15
14
13
12
11
MOTOR DRIVER IC
21
1a
1b

FIG.2


154a2
154b
155a
154a1
Y
X
15
15b
154
154b
15a
154b
154b
156e
156
156d
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156a
156c
157
155
154c
158
155b
159
153
151
152
F
12

FIG.3

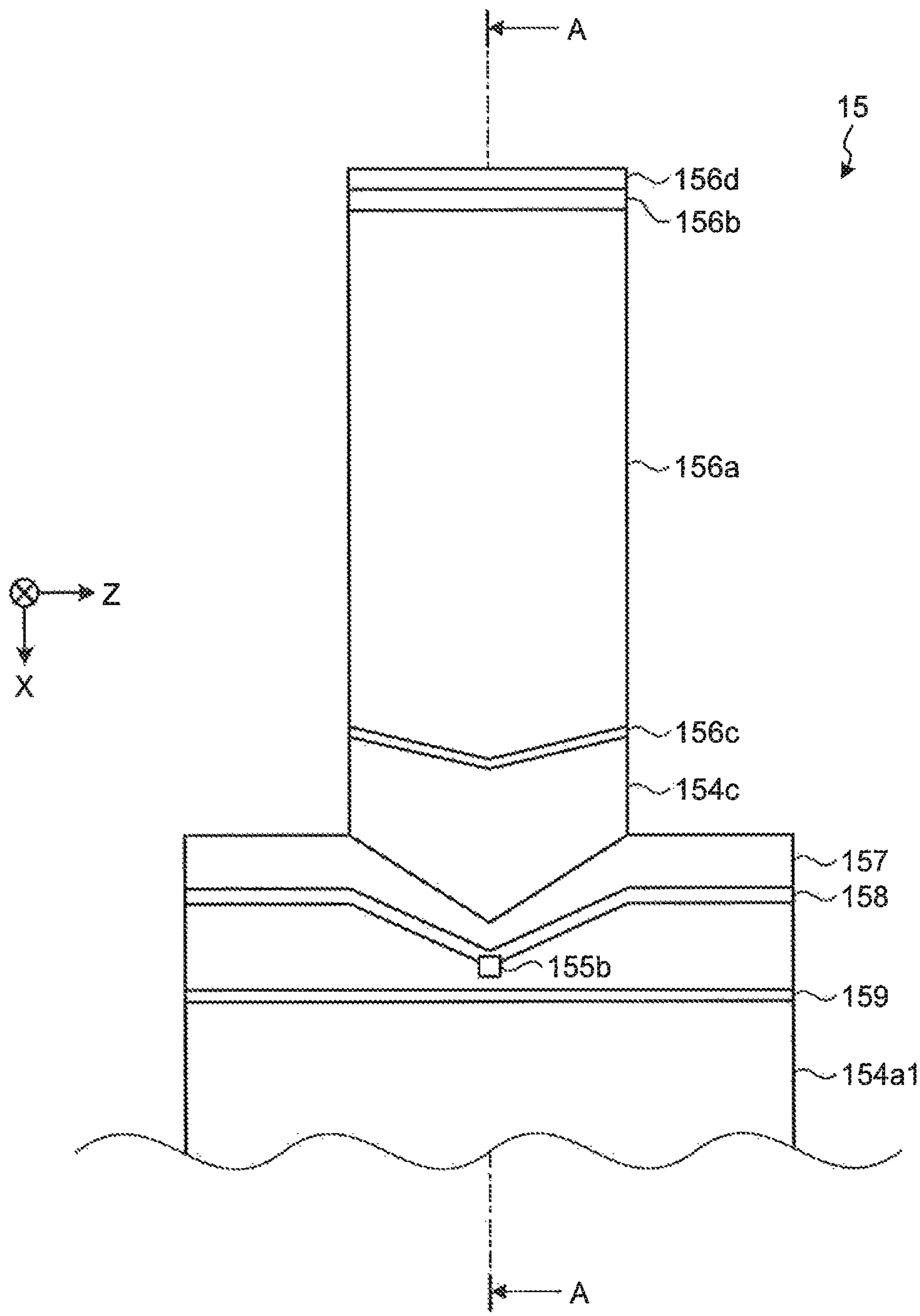


FIG.4

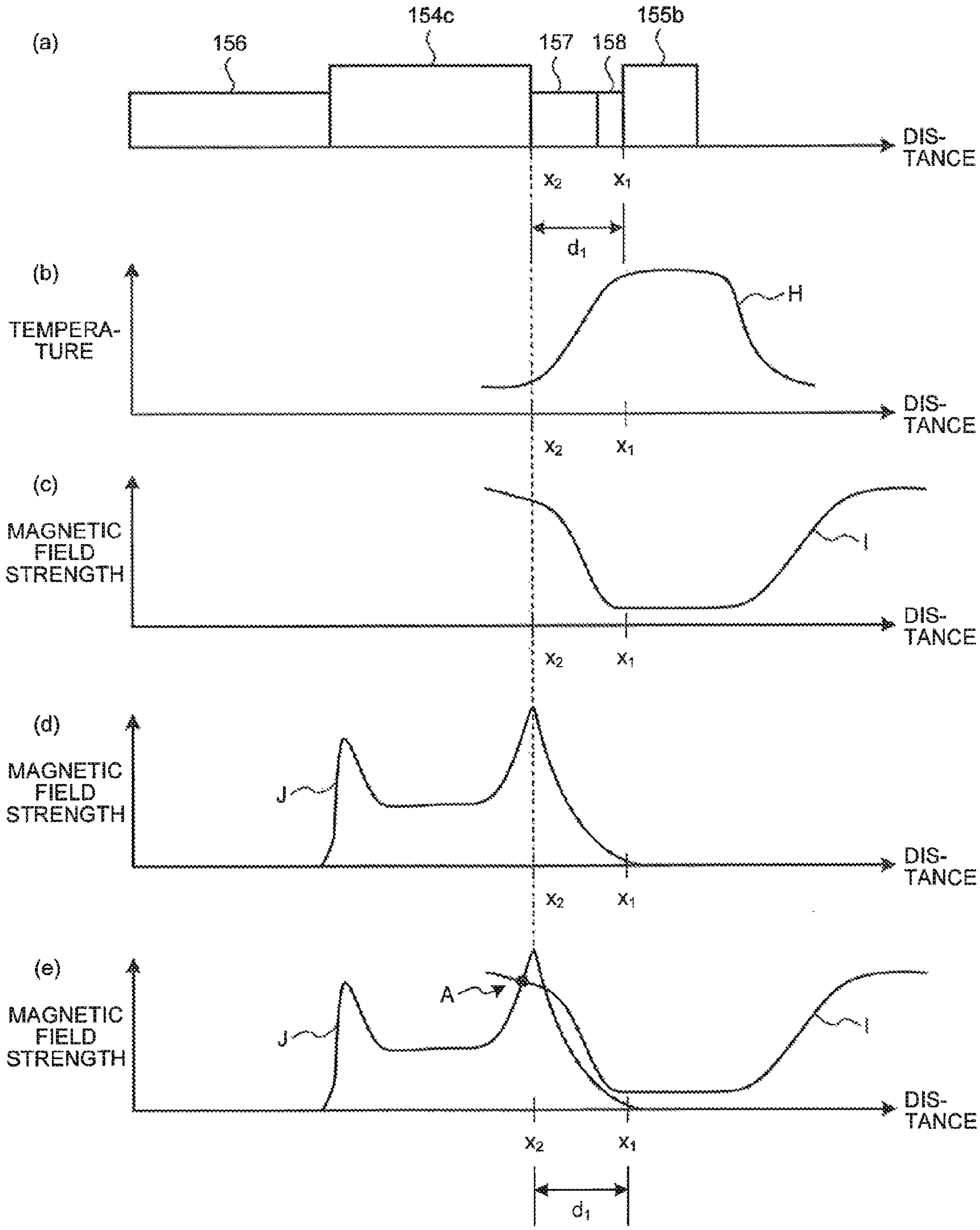

(a)
156
154c
157
158
155b
DIS-
TANCE
x_2
x_1
d_1
(b)
TEMPERA-
TURE
H
DIS-
TANCE
x_2
x_1
(c)
MAGNETIC
FIELD
STRENGTH
I
DIS-
TANCE
x_2
x_1
(d)
MAGNETIC
FIELD
STRENGTH
J
DIS-
TANCE
x_2
x_1
(e)
MAGNETIC
FIELD
STRENGTH
A
J
I
DIS-
TANCE
x_2
x_1
d_1

FIG.5

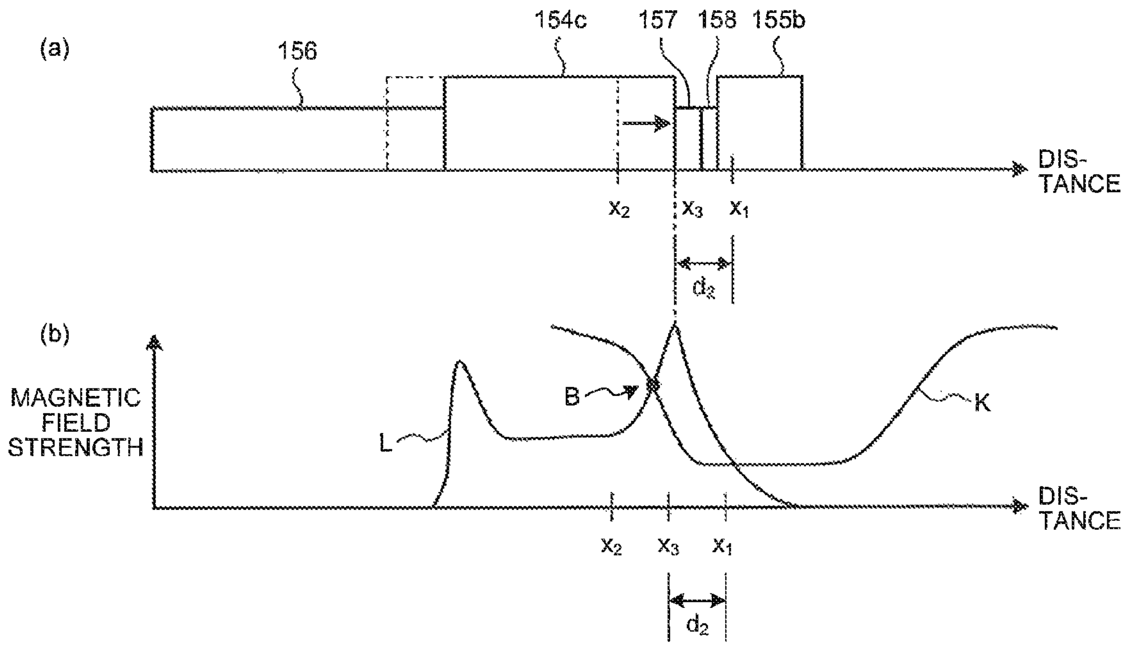

(a)
156
154c
157
158
155b
DIS-
TANCE
x_2
x_3
x_1
d_2
(b)
MAGNETIC
FIELD
STRENGTH
L
B
K
DIS-
TANCE
x_2
x_3
x_1
d_2

FIG.6

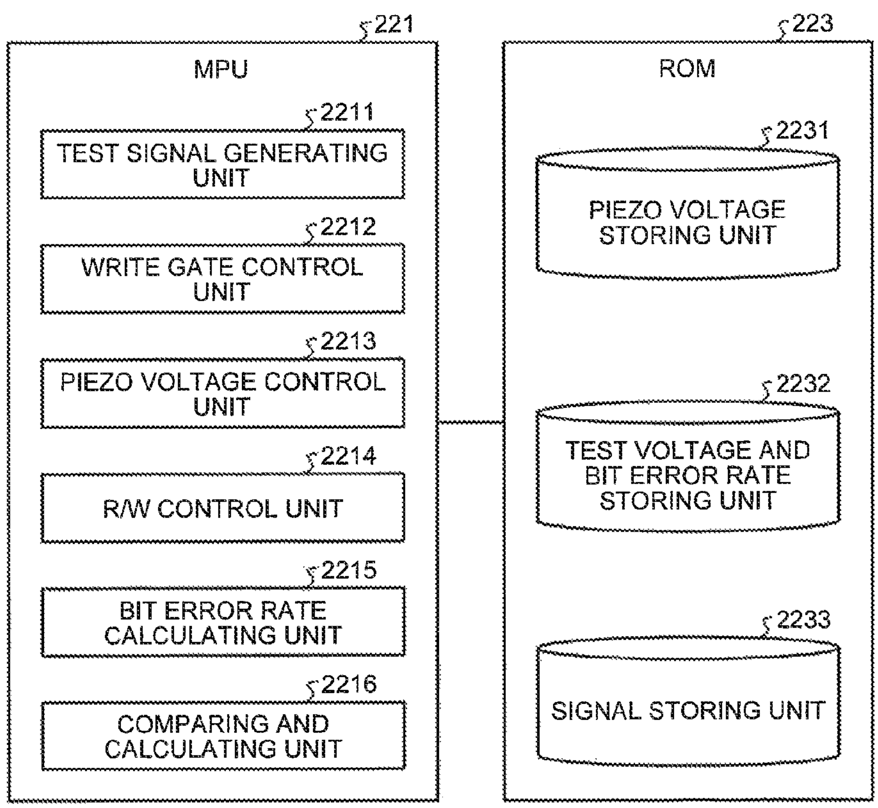

221
MPU
2211
TEST SIGNAL GENERATING UNIT
2212
WRITE GATE CONTROL UNIT
2213
PIEZO VOLTAGE CONTROL UNIT
2214
R/W CONTROL UNIT
2215
BIT ERROR RATE CALCULATING UNIT
2216
COMPARING AND CALCULATING UNIT
223
ROM
2231
PIEZO VOLTAGE STORING UNIT
2232
TEST VOLTAGE AND BIT ERROR RATE STORING UNIT
2233
SIGNAL STORING UNIT

FIG.7

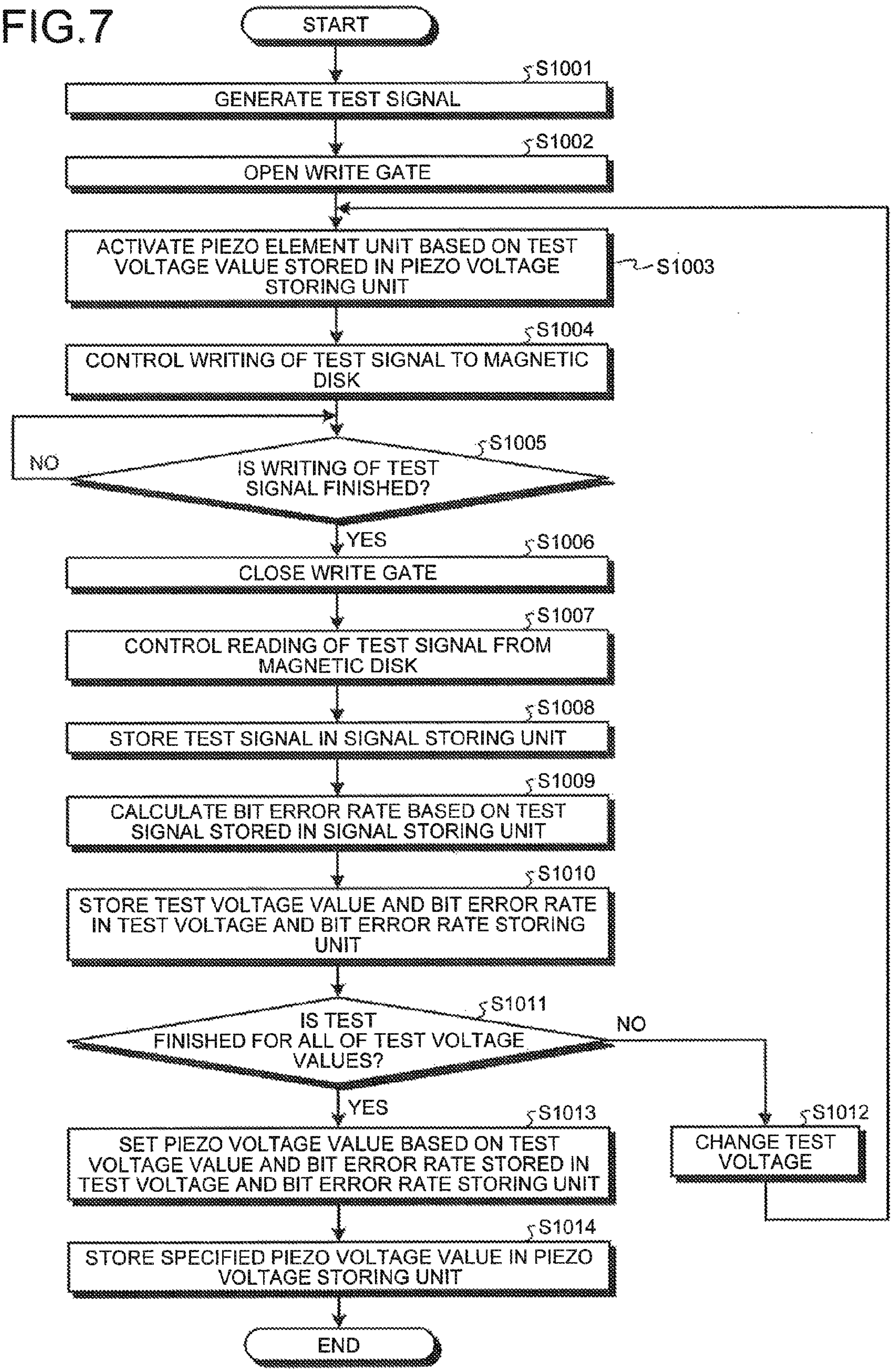

START
S1001
GENERATE TEST SIGNAL
S1002
OPEN WRITE GATE
ACTIVATE PIEZO ELEMENT UNIT BASED ON TEST VOLTAGE VALUE STORED IN PIEZO VOLTAGE STORING UNIT
S1003
S1004
CONTROL WRITING OF TEST SIGNAL TO MAGNETIC DISK
S1005
NO
IS WRITING OF TEST SIGNAL FINISHED?
YES
S1006
CLOSE WRITE GATE
S1007
CONTROL READING OF TEST SIGNAL FROM MAGNETIC DISK
S1008
STORE TEST SIGNAL IN SIGNAL STORING UNIT
S1009
CALCULATE BIT ERROR RATE BASED ON TEST SIGNAL STORED IN SIGNAL STORING UNIT
S1010
STORE TEST VOLTAGE VALUE AND BIT ERROR RATE IN TEST VOLTAGE AND BIT ERROR RATE STORING UNIT
S1011
IS TEST FINISHED FOR ALL OF TEST VOLTAGE VALUES?
NO
YES
S1013
SET PIEZO VOLTAGE VALUE BASED ON TEST VOLTAGE VALUE AND BIT ERROR RATE STORED IN TEST VOLTAGE AND BIT ERROR RATE STORING UNIT
S1012
CHANGE TEST VOLTAGE
S1014
STORE SPECIFIED PIEZO VOLTAGE VALUE IN PIEZO VOLTAGE STORING UNIT
END

FIG.8

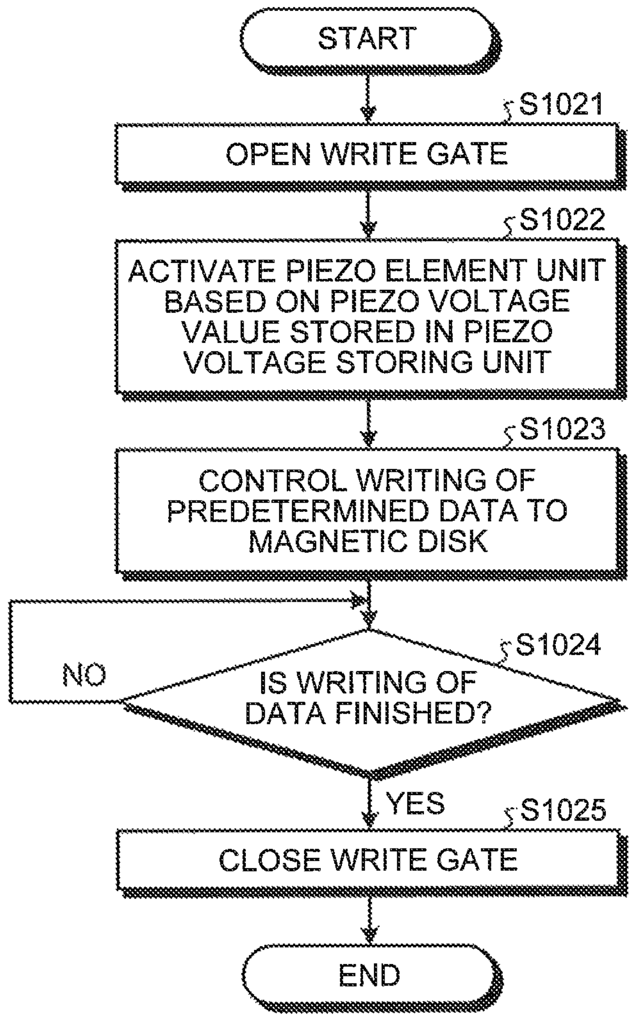
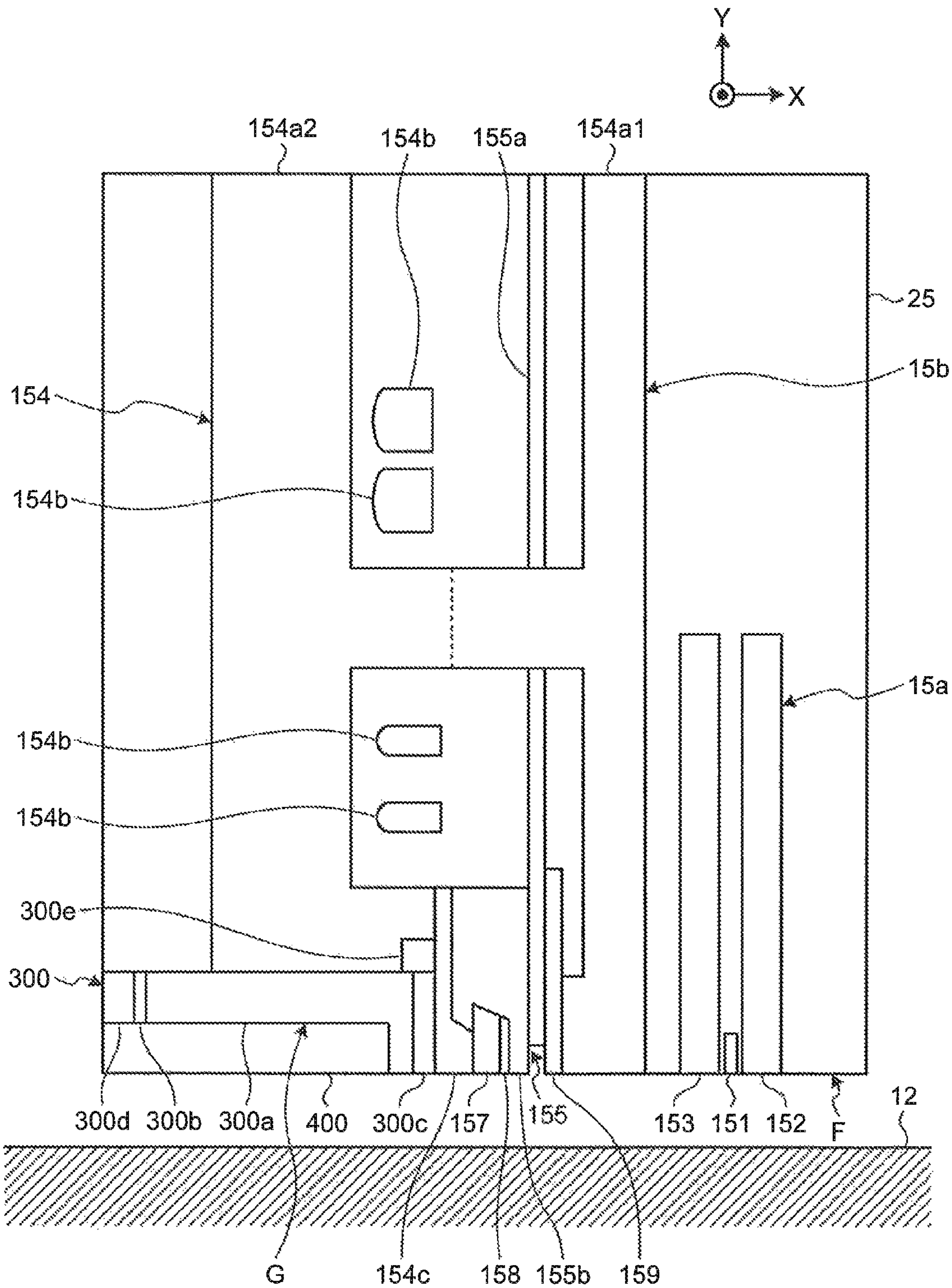

START
S1021
OPEN WRITE GATE
S1022
ACTIVATE PIEZO ELEMENT UNIT BASED ON PIEZO VOLTAGE VALUE STORED IN PIEZO VOLTAGE STORING UNIT
S1023
CONTROL WRITING OF PREDETERMINED DATA TO MAGNETIC DISK
S1024
IS WRITING OF DATA FINISHED?
NO
YES
S1025
CLOSE WRITE GATE
END

FIG.9



Y
X
154a2
154b
155a
154a1
25
15b
154
154b
15a
154b
154b
300e
300
300d
300b
300a
400
300c
157
155
153
151
152
F
12
G
154c
158
155b
159

MAGNETIC HEAD AND MAGNETIC DISK DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2014-179487, filed on Sep. 3, 2014; the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a magnetic head and a magnetic disk device.

BACKGROUND

Conventionally, there has been known a magnetic disk device provided with a magnetic head that performs thermally assisted magnetic recording by using near-field light with respect to a magnetic disk having high coercivity. In such a device, the magnetic head includes: a near-field light generating element that generates near-field light; and a magnetic pole for writing data to a magnetic disk. Upon writing data to the magnetic disk, such a device temporarily and locally heats up the magnetic disk by the near-field light generated by the near-field light generating element. Then, the device writes data with respect to a region of the magnetic disk at which coercivity is decreased by the heating. Consequently, the recording density of the magnetic disk is increased.

Recently, for such a magnetic disk device, it is desired to further improve writing quality with respect to the magnetic disk.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating a hardware configuration of a magnetic disk device according to a first embodiment;

FIG. **2** is a cross sectional view of a magnetic head according to the first embodiment;

FIG. **3** is a view looking at a portion of the magnetic head from a floating surface side of the magnetic head, according to the first embodiment;

FIG. **4** is a diagram for explaining a position at which a signal is written, before changing a distance between a magnetic pole and a near-field light generating unit, according to the first embodiment;

FIG. **5** is a diagram for explaining the position at which the signal is written, after changing the distance between the magnetic pole and the near-field light generating unit, according to the first embodiment;

FIG. **6** is a block diagram illustrating functional configurations realized by a micro processing unit (MPU) and interior configurations of a read only memory (ROM), according to the first embodiment;

FIG. **7** is a flowchart illustrating a piezo voltage setup process according to the first embodiment;

FIG. **8** is a flowchart illustrating a data write process according to the first embodiment; and

FIG. **9** is a cross sectional view illustrating a magnetic head according to a second embodiment.

DETAILED DESCRIPTION

In general, according to one embodiment, a magnetic head is arranged opposite a magnetic recording medium comprising a recording layer. The magnetic head comprises a magnetic pole, a light emitting unit, and a distance adjusting unit. The magnetic pole comprises a soft magnetic material. The light emitting unit is arranged with respect to the magnetic pole in a travel direction of the magnetic head, and emits light with respect to the recording layer. The distance adjusting unit adjusts a distance between the magnetic pole and the light emitting unit.

Exemplary embodiments of a magnetic head and a magnetic disk device will be explained below in detail with reference to the accompanying drawings. The present invention is not limited to the following embodiments.

First Embodiment

A first embodiment is described with reference to FIGS. **1** to **8**. FIG. **1** is a diagram illustrating a hardware configuration of a magnetic disk device **1** of the present embodiment. The magnetic disk device **1** comprises a disk enclosure **1***a* and a circuit board **1***b*.

The disk enclosure **1***a* comprises a housing **11**, a magnetic disk **12**, a spindle **13**, a spindle motor (SPM) **14**, a magnetic head **15**, a slider **16**, a suspension **17**, an arm actuator **18**, a voice coil motor (VCM) **19**, and a head integrated chip (IC) **20**. The circuit board **1***b* comprises a motor driver IC **21** and a system-on-a-chip (SoC) **22**. In order to simplify explanations, the head IC **20** is arranged outside the housing **11** in FIG. **1**. However, the head IC **20** is in fact arranged at a predetermined location of the arm actuator **18**.

The magnetic disk **12** is a disk-shaped recording medium that records therein various information. The magnetic disk **12** is configured to be writable by a perpendicular magnetic recording (PMR) scheme. The magnetic disk **12** has a recording layer with magnetic anisotropy along a substantially vertical direction with respect to a medium surface of the magnetic disk **12**. A magnetic body of the magnetic recording layer is magnetized in a substantially vertical direction with respect to the surface (medium surface) of the magnetic disk **12** by the magnetic field applied by the later-described magnetic head **15**. Further, for the magnetic recording layer of the magnetic disk **12**, a material having high coercivity at room temperature is used.

The magnetic disk **12** is rotatably fixed to the housing **11** via the spindle **13**. The SPM **14** indirectly rotates the magnetic disk **12** by applying torque on the spindle **13**.

As is described in details later, the magnetic head **15** is configured to read and write signals and data with respect to the magnetic disk **12**. The magnetic head **15** is provided at an end of the slider **16** in an elongated direction of the slider **16**. Here, the slider **16** floats over the magnetic disk **12** by receiving an air flow generated by the rotation of the magnetic disk **12**. The slider **16** is connected to the arm actuator **18** via the suspension **17** which allows the floating of the magnetic head **15**. The arm actuator **18** swings in a direction along a recording surface of the magnetic disk **12** by the VCM **19**. Consequently, the magnetic head **15** can read and write signals and data with respect to any location on the magnetic disk **12**.

The head IC **20** is electrically connected to the magnetic head **15** and the SoC **22**. The head IC **20** amplifies the signals and data read out from the magnetic disk **12** by the magnetic head **15**, and outputs the read out signals and data to the SoC **22** described later. Further, the head IC **20** amplifies the signals and data output from the SoC **22**, and outputs the amplified signals and data to the magnetic head **15**. Still further, the head IC **20** outputs a test voltage and a piezo voltage described later to the magnetic head **15**.

The motor driver IC **21** is connected to the SPM **14**, the VCM **19**, and the SoC **22**. The motor driver IC **21** controls the SPM **14** and the VCM **19** in accordance with a control signal from the SoC **22** to control a positioning of the magnetic head **15** with respect to the magnetic disk **12**.

The SoC **22** comprises a micro processing unit (MPU) **221**, a random access memory (RAM) **222**, a read only memory (ROM) **223**, a read and write (R/W) channel **224**, and a hard disk controller (HDC) **225**.

The MPU **221** is connected to the motor driver IC **21**, the RAM **222**, the ROM **223**, and the R/W channel **224**. The MPU **221** controls operations of various units and portions of the magnetic disk device **1**. In particular, the MPU **221** sequentially reads and executes a firmware and various applications stored in the ROM **223** to control operations of each portion and unit of the magnetic disk device **1**. The ROM **223** stores therein the firmware, various applications, and various data required to execute the firmware and various applications. The RAM **222** provides a work area for when the MPU **221** executes the firmware and/or the applications, as a main memory of the magnetic disk device **1**.

The R/W channel **224** is connected to the MPU **221**, the HDC **225**, and the head IC **20**. The R/W channel **224** performs a predetermined signal processing on data output from the HDC **225**, and outputs it to the head IC **20**. Further, the R/W channel **224** outputs a test signal generated by the MPU **221** to the head IC **20**. Further, the R/W channel **224** generates a write gate signal and outputs it to the head IC **20**. Further, the R/W channel **224** instructs the head IC **20** to output the test voltage and the piezo voltage described later. Further, the R/W channel **224** performs a predetermined signal processing on signals and data output from the head IC **20**, and outputs them to the HDC **225** and/or the MPU **221**.

The HDC **225** is connected to the ROM **223**, the R/W channel **224**, and a host computer not illustrated. The HDC **225** constitutes an interface for the host computer. The HDC **225** outputs data received from the host computer to the R/W channel **224**, and outputs data received from the R/W channel **224** to the host computer.

Next, a configuration of the magnetic head **15** is described based on FIGS. **2** and **3**. FIG. **2** is a cross sectional view of the magnetic head **15** on an XY plane. FIG. **3** is a plan view of a portion of a face of the magnetic head **15** opposing the magnetic disk **12**, looking up the portion from the magnetic disk **12** side. Herein, a head travel direction means a direction toward which the magnetic head **15** moves relative to the magnetic disk **12** due to the rotation of the magnetic disk **12**, and is equivalent to +X direction in FIGS. **2** and **3**. The X-axis, the Y-axis, and the Z-axis in FIG. **2** are orthogonal to each other. The X-axis, the Y-axis, and the Z-axis in FIG. **3** are orthogonal to each other. The X-axis, the Y-axis, and the Z-axis of FIG. **2** correspond to the X-axis, the Y-axis, and the Z-axis of FIG. **3**, respectively. Further, in the following explanations, a face of the magnetic head **15** opposing the magnetic disk **12** is referred to as a floating surface F of the magnetic head **15**. Further, although not illustrated, the floating surface F of the magnetic head is covered entirely by a protective coating such as, e.g., an acrylonitrile butadiene styrene (ABS) resin.

First, a configuration of the magnetic head **15** is described with reference to FIG. **2**. Here, FIG. **2** is also a cross sectional view of the magnetic head **15** taken along a line A-A illustrated in FIG. **3**. As illustrated in FIG. **2**, the magnetic head **15** roughly comprises: a reproduction unit **15***a* configured to be capable of reading signals and/or data written on the magnetic disk **12**; and a recording unit **15***b* capable of writing signals and/or data to the magnetic disk **12**.

The reproduction unit **15***a* comprises a reproduction element **151** and two shields **152**, **153**. The reproduction element **151** is arranged between the shields **152**, **153** in the X-axis direction. At least a portion of the reproduction element **151** is exposed to the floating surface F via the protective coating not illustrated. The reproduction element **151** is a tunnel magneto-resistance (TMR) element, and reads out the signals and/or data written on the magnetic disk **12** via a sense current. The shields **152**, **153** function as magnetic shields as well as electrodes that supplies the sense current of the reproduction element **151**. A wiring not illustrated is connected to each of the shields **152**, **153**. A voltage for supplying the sense current to the reproduction element **151** is applied to the each of the shields **152**, **153** from the head IC **20**. In the present embodiment, the example is explained in which the TMR element is used as the reproduction element **151**. However, the present embodiment is not limited thereto, and any configuration such as a giant magneto-resistance (GMR) element can be employed as the reproduction element **151** as long as the configuration can read out data written on the magnetic disk **12**.

The recording unit **15***b* comprises a magnetic core unit **154**, a light generating unit **155**, a piezo element unit **156**, a magnetic pole position control unit **157**, a heat dissipating unit **158**, and a rigid member **159**.

The magnetic core unit **154** comprises a magnetic yoke **154***a*, a coil **154***b*, and a magnetic pole **154***c*.

The magnetic yoke **154***a* is integrally formed by a leading yoke **154***a***1** and a trailing yoke **154***a***2**. Each of the leading yoke **154***a***1** and the trailing yoke **154***a***2** is formed of a high saturation density material. The leading yoke **154***a***1** has a substantially inverse F-shape in the cross section of the magnetic head **15** as illustrated in FIG. **2**. The trailing yoke **154***a***2** has a shape obtained by rotating the substantially inverse F-shape of the leading yoke **154***a***1** by 180 degrees around the Y-axis, in the cross section of the magnetic head **15** illustrated in FIG. **2**. The leading yoke **154***a***1** and the trailing yoke **154***a***2** are arranged to oppose each other, and are connected to each other at a middle part (a part near a winding center of the coil **154***b*) in the Y-axis direction. A distal end of the leading yoke **154***a***1** located on the floating surface F side is exposed to the floating surface F via the protective coating. A distal end of the trailing yoke **154***a***2** located on the floating surface F side is covered by the piezo element unit **156** described later. Here, the leading yoke **154***a***1** and the trailing yoke **154***a***2** of the present embodiment can be made of the same material, or can be formed by different material.

The coil **154***b* is would around a center of the trailing yoke **154***a***2** in the Y-axis direction. The coil **154***b* is connected to the head IC **20** via a wiring not illustrated, and generates a magnetic field from the magnetic yoke **154***a* by the current output from the head IC **20**. The magnetic field generated by the coil **154***b* is applied from the magnetic pole **154***c* to the magnetic disk **12** in a substantially vertical direction with respect to the magnetic recording surface.

The magnetic pole **154***c* is arranged on the distal end of the trailing yoke **154***a***2** at the floating surface F side. Further, the magnetic pole **154***c* is arranged adjacent to the trailing yoke **154***a***2** in front of the distal end of the trailing yoke **154***a***2** in the head travel direction. The magnetic pole **154***c* is exposed on the floating surface F via the protective coating. The magnetic pole **154***c* is formed by high Bs material, unlike the trailing yoke **154***a***2**.

The light generating unit **155** comprises a light guide **155***a* and a light emitting unit **155***b*.

The light guide **155***a* is arranged between the light emitting unit **155***b* and the rigid member **159** in the X-axis direction at near the floating surface F. Further, the light guide **155**a is extended in +Y direction of FIG. **2** from near the floating surface F, and connected to a light source. The light guide **155**a guides light (e.g., laser light) supplied by the light source to the light emitting unit **155**b. An end of the light guide **155**a at the floating surface side is separated from the floating surface F in the +Y direction.

At near the floating surface F, the light emitting unit **155**b is arranged in front of the magnetic pole **154**c in the head travel direction. In particular, the light emitting unit **155**b is arranged between the heat dissipating unit **158** described later and the light guide **155**a in the X-axis direction. The light emitting unit **155**b has an opening of a length equal to or less than a wavelength of the light supplied by the light source, and forms the near-field light around the opening by the light guided through the light guide **155**a. Then, the light emitting unit **155**b locally emits the formed near-field light with respect to the magnetic disk **12**. That is to say, the light emitting unit **155**b generates the near-field light. Consequently, writing of the signals and/or data by the magnetic field generated by the magnetic pole **154**c with respect to a position of the magnetic disk **12** at which the near-field light is irradiated locally is assisted. Here, the light guide **155**a is arranged so as to be separated from the floating surface F in a direction separating from the magnetic disk **12** (in other word, so as to recess with respect to the floating surface F).

The piezo element unit **156** comprises a piezo element **156**a, two piezo electrodes **156**b, **156**c, and two piezo terminals **156**d, **156**e.

The two piezo electrodes **156**b, **156**c are arranged on ends of the piezo element **156**a in the X-axis direction, respectively. The two piezo electrodes **156**b, **156**c function as electrodes for applying voltage on the piezo element **156**a.

The two piezo terminals **156**d, **156**e are connected to the piezo electrodes **156**b, **156**c, respectively, and also connected to the head IC **20** through wirings not illustrated.

The piezo element **156**a is arranged on the floating surface F so that the elongated direction thereof coincides with the X-axis direction. Further, the piezo element **156**a is arranged behind the magnetic pole **154**c in the head travel direction. In the present embodiment, the piezo element **156**a is a piezoelectric element. The piezo element **156**a extends/expands in an elongated direction thereof by being applied the voltage via the piezo electrodes **156**b, **156**c, in accordance with an instruction from the head IC **20**. As a result, the piezo element **156**a pushes the magnetic pole **154**c toward the head travel direction. That is to say, the piezo element **156**a can move the magnetic pole **154**c in the +X direction. In other word, the piezo element unit **156** adjusts a distance between the magnetic pole **154**c and the light emitting unit **155**b in the head travel direction.

The magnetic pole position control unit **157** is arranged between the magnetic pole **154**c and the heat dissipating unit **158** in the X-axis direction, at nearby the floating surface F. The magnetic pole position control unit **157** is formed of, for example, SiO_2 or $LiAlSiO_4$, and has a negative thermal expansion coefficient. In the present embodiment, it is explained a case in which the magnetic pole position control unit **157** contracts due to generated heat around the magnetic pole **154**c when the data is written to the magnetic disk **12**. However, the present embodiment is not limited thereto.

The heat dissipating unit **158** is arranged between the magnetic pole position control unit **157** and the light emitting unit **155**b in the X-axis direction, at nearby the floating surface F. The heat dissipating unit **158** is formed of a body with high thermal conductivity such as, for example, gold (Au) or copper (Cu). The heat dissipating unit **158** dissipates, for example, excess heat due to the near-field light generated by the light emitting unit **155**b.

The rigid member **159** is arranged in front of the light emitting unit **155**b in the head travel direction, at nearby the floating surface F. Further, the rigid member **159** is extended in the +Y direction in FIG. **2** from near the floating surface F. The rigid member **159** is formed of, for example, a low thermal expansion material. When the position of the magnetic pole **154**c is changed in the head travel direction due to the elongation/expansion of the piezo element **156**a, the rigid member **159** prevents the position of the light emitting unit **155**b to be pushed and changed in the head travel direction.

Next, there are explained arrangements of major configurations of the magnetic head on the floating surface F. As illustrated in FIG. **3**, the magnetic head **15** comprises, on the floating surface F and in the direction from the back to the front of the magnetic head **15** in the head travel direction, the piezo terminal **156**d, the piezo electrode **156**b, the piezo element **156**a, the piezo electrode **156**c, the magnetic pole **154**c, the magnetic pole position control unit **157**, the heat dissipating unit **158**, the light emitting unit **155**b, the rigid member **159**, and the leading yoke **154**a**1**, in this order. Although the light guide **155**a is arranged between the light emitting unit **155**b and the rigid member **159**, it is not apparent on the floating surface F because the light guide **155**a is recessed from the floating surface F.

According to a magnetic disk device in which a magnetic head for performing a thermally assisted magnetic recording by using near-field light is installed, a near-field light generating element and a magnetic pole are arranged by taking into account the timing of heating by the near-field light and the timing of applying the magnetic field. However, sometimes the magnetic field cannot be applied at a position at which a gradient of a temperature distribution is steep, due to manufacturing error of the magnetic disk device or slight difference in coercivity.

FIG. **4** is a diagram for explaining an example in which the magnetic pole **154**c and the light emitting unit **155**b are arranged apart from each other due to the manufacturing error and the like of the magnetic disk device and therefore the magnetic field cannot be applied at a position at which the gradient of the temperature distribution of the surface temperature of the magnetic disk **12** is steep. In this example, as illustrated in (a) of FIG. **4**, the position x_1 of the light emitting unit **155**b is separated from the position x_2 of the magnetic pole **154**c by a distance d_1, in the head travel direction.

(b) of FIG. **4** illustrates the temperature distribution of the surface temperature of the magnetic disk **12** heated by the light emitting unit **155**b of (a) of FIG. **4**, as a curve H. (c) of FIG. **4** illustrates distribution of magnetic field strength required to magnetize the magnetic disk **12** with a coercivity weaken by the heat, as a curve I. (d) of FIG. **4** illustrates distribution of magnetic field strength generated by the magnetic pole **154**c at the time of writing, as a curve J. (e) of FIG. **4** illustrates the curve I and the curve J on the same diagram. Here, positions in the X-axis direction correspond to each other among (a) to (e) of FIG. **4**.

As is clear from FIG. **4**, the distribution of the magnetic field strength required to invert the magnetization of the magnetic disk heated by the light emitting unit **155**b is the curve I in (c) of FIG. **4**, and the distribution of the magnetic field strengths formed by the magnetic pole **154**c at the time of writing is the curve J in (d) of FIG. **4**. Therefore, if the magnetic pole **154**c and the light emitting unit **155**b have the positional relationship illustrated in (a) of FIG. **4**, the magnetic field to be applied at the time of writing is applied at a position A, as illustrated in (e) of FIG. **4**. Here, the position A has gradient comparatively gentle as compared to the steepest gradient in the distribution (the curve I) of the magnetic field strength required to invert the magnetization. As a result, quality at the time of writing data, such as the signal-to-noise ratio and/or the bit error data, might be degraded.

Hence, according to the present embodiment, the distance between the magnetic pole **154***c* and the light emitting unit **155***b* is adjusted by the piezo element unit **156** at the time of testing and/or the like that is performed after assembling the magnetic disk device but before its shipment. Consequently, it becomes possible to apply the magnetic field at a position where the gradient of the temperature distribution of the surface temperature of the magnetic disk **12** is steep.

FIG. **5** is a diagram for explaining an example after the distance between the magnetic pole **154***c* and the light emitting unit **155***b* is adjusted by the piezo element unit **156**. In this example, as illustrated in (a) of FIG. **5**, the magnetic pole **154***c* corresponding to a distance not yet being adjusted, as illustrated by a dotted line at a position X_2, is moved to a position X_3 in the head travel direction (the arrow direction in (a) of FIG. **5**). Accordingly, the distance between the magnetic pole **154***c* and the light emitting unit **155***b* is changed to a distance d_2. As a result, as illustrated in (b) of FIG. **5**, the magnetic field to be applied at the time of writing can be applied at a position B where the gradient is comparatively steep as compared to the gradient of other positions of the distribution (a curve K) of the magnetic field strengths required to invert the magnetization. Consequently, the quality at the time of writing data, such as the signal-to-noise ratio and/or the bit error rate, can be improved. Here, the curve K in (b) of FIG. **5** is distribution of magnetic field strength required to invert magnetization of the magnetic disk heated by the light emitting unit **155***b*. Further, the curve L in (b) of FIG. **5** is distribution of magnetic field strength formed by the magnetic pole **154***c* at the time of writing.

Next, functions realized by the MPU **221** when processing (hereinafter, referred to as piezo voltage setting process) for adjusting the distance between the magnetic pole **154***c* and the light emitting unit **155***b* is executed and various units of the ROM **223** referred to at the time of the piezo voltage setting process are explained. The piezo voltage setting process is realized by a program stored in the ROM **223**.

The MPU **221** executes a program stored in the ROM **223** to realize each function illustrated in FIG. **6** (a test signal generating **2211**, a write gate control unit **2212**, a piezo voltage control unit **2213**, a read and write (R/W) control unit **2214**, a bit error rate calculating unit **2215**, a comparing and calculating unit **2216**). That is to say, the MPU **221** comprises a plurality of functional units illustrated in FIG. **6**. The ROM **223** comprises a piezo voltage storing unit **2231**, a piezo voltage and bit error rate storing unit **2232**, and a signal storage unit **2233**. The piezo voltage storing unit **2231** preliminarily stores therein a plurality of candidate voltage values specified at the time of manufacture of the magnetic disk device **1**, for example. The piezo voltage storing unit **2231** stores therein a piezo voltage determined by the piezo voltage setting process. The test voltage and bit error rate storing unit **2232** stores therein the test voltage and the bit error rate in association with each other. The signal storing unit **2233** stores therein the test signals read out from the magnetic disk **12**.

The test signal generating unit **2211** generates a predetermined test signal that is to be experimentally written to the magnetic disk **12** at the time of determining the piezo voltage. The write gate control unit **2212** controls the output of the write gate signal by the R/W channel **224**. The piezo voltage control unit **2213** acquires the candidate voltage values and/or the piezo voltage values from the piezo voltage storing unit **2231**, and controls applying a voltage corresponding to the acquired voltage value on the piezo element unit **156**. The R/W control unit **2214** controls writing the test signal generated by the test signal generating unit **2211** to the magnetic disk **12**. Further, the R/W control unit **2214** controls storing the test signal written to the magnetic disk **12** in the signal storing unit **2233**. The bit error rate calculating unit **2215** calculates a bit error rate of the test signal stored in the signal storing unit **2233**. Further, the bit error rate calculating unit **2215** stores the calculated bit error rate in the piezo voltage and bit error rate storing unit **2232** in association with the candidate voltage value used to write the corresponding test signal. The comparing and calculating unit **2216** compares the bit error rates stored in the piezo voltage and bit error rate storing unit **2232** with each other. Then, the comparing and calculating unit **2216** specifies one of the candidate voltage values associated with the lowest bit error rate as a piezo voltage value, and stores the specified piezo voltage value in the piezo voltage storing unit **2231**.

Next, the piezo voltage setting process is explained with reference to FIG. **7**. FIG. **7** is a flowchart of the piezo voltage setting process. First, the test signal generating unit **2211** generates the test signal (S**1001**). Then, the write gate control unit **2212** controls the R/W channel **224** to open the write gate (S**1002**).

Next, the piezo voltage control unit **2213** refers to the piezo voltage storing unit **2231**, and acquires one of the stored candidate voltage values as a test voltage value. Then, the piezo voltage control unit **2213** controls the activation of the piezo element unit **156** based on the acquired voltage value (S**1003**).

Next, the R/W control unit **2214** controls the writing of the test signal to the magnetic disk **12** (S**1004**). In particular, the R/W control unit **2214** controls to cause the current to flow through the coil **154***b* of the magnetic head **15** in accordance with the test signal generated by the test signal generating unit **2211**. Then, the R/W control unit **2214** determines whether the writing of the test signal to the magnetic disk **12** is completed (S**1005**). When it is determined that the writing of the test signal has not been completed (No at S**1005**), the R/W control unit **2214** repeats the process of S**1005** until the writing of the test signal is completed. On the other hand, when it is determined that the writing of the test signal has been completed (Yes at S**1005**), the write gate control unit **2212** closes the write gate (S**1006**).

Next, the R/W control unit **2214** performs control to read the test signal written to the magnetic disk **12** (S**1007**). Then, the R/W control unit **2214** stores the read test signal to the signal storing unit **2233** (S**1008**). Subsequently, the bit error rate calculating unit **2215** acquires the test signal from the signal storing unit **2233**, and calculates the bit error rate based on the acquired test signal (S**1009**). Further, the bit error rate calculating unit **2215** stores the test voltage value used for writing the test signal for which the bit error rate is calculated at S**1009** in the test voltage and bit error rate storing unit **2232** in association with the bit error rate calculated at S**1009** (S**1010**).

Next, the comparing and calculating unit **2216** determines whether the test signal is written by using all of the candidate voltage values stored in the piezo voltage storing unit **2231** (S**1011**). If it is determined that the test signal has not been written by using all of the candidate voltage values (No at S**1011**), the piezo voltage control unit **2213** sets one of the candidate voltage values stored in the piezo voltage storing unit **2231** and that has not yet been tested, as the test voltage value (i.e., change the test voltage) (S**1012**), and repeats the process from S**1003**.

On the other hand, if it is determined that the test signal is written by using all of the candidate voltage values stored in the piezo voltage storing unit **2231** (S**1011**), the comparing and calculating unit **2216** compares the bit error rates stored in the test voltage and bit error rate storing unit **2232** with each other. Then, the comparing and calculating unit **2216** specifies one of the candidate voltage values associated with the lowest bit error rate as a piezo voltage value (S**1013**). Subsequently, the comparing and calculating unit **2216** stores the specified piezo voltage value in the piezo voltage storing unit **2231** (S**1014**). Consequently, the piezo voltage setting process is finished.

Next, processing performed when data is written by using the piezo voltage value set by the piezo voltage setting process is explained with reference to FIG. **8**. FIG. **8** is a flowchart of data write process performed by using the stored piezo voltage value. Here, the data write process is a process to write user data instructed to be written by a personal computer and/or the like to the magnetic disk.

First, the MPU **221** performs control to open the write gate (S**1021**). Next, the MPU **221** acquires the piezo voltage value that is stored in the piezo voltage storing unit **2231** as a result of the piezo voltage setting process. Then, the MPU **221** performs control to apply voltage corresponding to the acquired piezo voltage value on the piezo element unit **156** (S**1022**). Consequently, the distance between the magnetic pole **154***c* and the light emitting unit **155***b* is adjusted in the head travel direction.

Next, the MPU **221** controls writing of predetermined data with respect to the magnetic disk **12** (S**1023**). In particular, the MPU **221** performs control to write data received from the host computer by the HDC **225** to the magnetic disk **12**. Then, the MPU **221** determines whether the writing of the data is completed (S**1024**). If it is determined that the writing of the data is not completed (No at S**1024**), the process at S**1024** is repeated until the writing of the data is completed.

On the other hand, if it is determined that the writing of the data is completed (Yes at S**1024**), the MPU **221** performs controls to close the write gate (S**1025**), and finishes the process.

As described above, according to the magnetic disk device **1** of the first embodiment, the magnetic head **15** is provided with the piezo element unit **156** which can adjust the distance between the magnetic pole **154***c* and the light emitting unit **155***b*. Consequently, it becomes capable of applying the magnetic field at the position where the gradient of the temperature distribution of the surface temperature of the magnetic disk **12** is steep. Thus, an effect in which the quality of writing with respect to the magnetic disk such as the signal-to-noise ratio and/or the bit error rate is improved can be obtained.

Second Embodiment

Next, a second embodiment is described with reference to FIG. **9**. FIG. **9** is a cross sectional diagram of a magnetic head **25** of the second embodiment. The magnetic head **25** of the present embodiment differs from the magnetic head **15** of the first embodiment in that, according to the magnetic head **25**, at least a portion of a piezo element unit **300** is arranged at a position separated from the floating surface F in the +Y direction. Thus, in the following, parts the same as that in the first embodiment are referred to by the same reference numerals, and the explanations thereof are omitted.

As illustrated in FIG. **9**, the magnetic head **25** comprises, at a side opposing the magnetic disk **12**: a substantially flat floating surface F; and a substantially flat surface G positioned away from the floating surface F in the +Y direction. That is to say, the magnetic head **25** includes a recessed portion at a rear end in the head travel direction as seen in the cross section of FIG. **9**. Then, at least a portion of the piezo element unit **300** is arranged on the surface G. The recessed portion is filled by a protective coating **400** such as the ABS. The floating surface side of the protective coating is formed in substantially flat together with the floating surface side of the magnetic pole **154***c* and the light emitting unit **155***b*.

As described above, according to the magnetic disk device of the second embodiment, the magnetic head **25** is provided with the piezo element unit **300** which can adjust the distance between the magnetic pole **154***c* and the light emitting unit **155***b*. Consequently, it becomes capable of applying the magnetic field at the position where the gradient of the temperature distribution of the surface temperature of the magnetic disk **12** is steep. Thus, an effect in which the quality of writing with respect to the magnetic disk such as the signal-to-noise ratio and/or the bit error rate is improved can be obtained.

Further, according to the second embodiment, the portion of the piezo element unit **300** is arranged at a position separated from the floating surface F in the direction separating from the magnetic disk **12**, and the protective coating **400** is provided on the floating surface side thereof. Thus, the portion of the piezo element unit **300** is protected by the protective coating **400**. Consequently, an effect in which the piezo electrodes and/or the like which corrodes comparatively easily can be protected can be obtained.

In the first and the second embodiments, the piezo voltage setting process is performed at the time of testing the magnetic disk, before the shipment thereof and after assembling the magnetic disk. However, the present embodiment is not limited thereto, and the piezo voltage setting process may be performed after the shipment of the magnetic disk device. Consequently, even if, for example, the piezo voltage of the magnetic disk device set at the time of shipment is no longer able to set the distance between the magnetic pole and the near-field light generating unit appropriately due to the degradation over time of the piezo element, it becomes capable of resetting an appropriate piezo voltage.

Further, in the first and the second embodiments, the distance between the magnetic pole and the near-field light generating unit is adjusted by using the piezo element. However, the present embodiment is not limited thereto, and any configuration such as any piezoelectric element and/or a current driven element can be employed as long as it can adjust the distance between the magnetic pole and the near-field light generating unit.

Further, in the first and the second embodiments, the distance between the magnetic pole and the near-field light generating unit is shortened by applying voltage to the piezo element. However, the present embodiment is not limited thereto, and any configuration such as a configuration that elongates the distance between the magnetic pole and the near field generating unit can be used, as long as such a configuration can adjust the distance between the magnetic pole and the near-field light generating unit to improve the quality of writing.

Further, in the first and the second embodiments, each of the test signal generating unit, the write gate control unit, the piezo voltage control unit, the R/W control unit, the bit error rate calculating unit, and the comparing and the calculating unit (hereinafter, referred to as the test signal generating unit and the like) is provided by executing the program stored in the ROM by the MPU. However, the present embodiment is not limited thereto, and at least one of the test signal generating unit and the like can be configured by a separate IC which differs from the MPU.

Further, in the first and the second embodiments, the bit error rate is calculated based on the test signal and the piezo voltage is set based on the calculated bit error rate. However, the present embodiment is not limited thereto, and any value such as for example the HSC can be calculated as long as such a value can verify the quality of writing of the test signal.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. A magnetic head that is arranged opposite a magnetic recording medium comprising a recording layer, the magnetic head comprising:

a magnetic pole comprising a soft magnetic material;

a light emitting unit arranged with respect to the magnetic pole in a travel direction of the magnetic head, and emits light with respect to the recording layer;

a distance adjusting unit that adjusts a distance between the magnetic pole and the light emitting unit; and

a magnetic pole position control unit having a negative thermal expansion coefficient, and arranged between the magnetic pole and the light emitting unit.

2. The magnetic head of claim **1**, wherein

the light emitting unit is arranged in front of the magnetic pole in the travel direction of the magnetic head, and

the distance adjusting unit is arranged behind the magnetic pole in the travel direction of the magnetic head.

3. A magnetic head that is arranged opposite a magnetic recording medium comprising a recording layer, the magnetic head comprising:

a magnetic pole comprising a soft magnetic material;

a light emitting unit arranged with respect to the magnetic pole in a travel direction of the magnetic head, and emits light with respect to the recording layer;

a distance adjusting unit that adjusts a distance between the magnetic pole and the light emitting unit; and

a rigid member arranged in front of the light emitting unit in the travel direction of the magnetic head and configured by a low thermal expansion material.

4. The magnetic head of claim **1**, wherein the distance adjusting unit is a piezoelectric element.

5. The magnetic head of claim **1**, wherein the light emitting unit generates near-field light based on laser light guided from an outside of the magnetic head.

6. A magnetic head that is arranged opposite a magnetic recording medium comprising a recording layer, the magnetic head comprising:

a magnetic pole comprising a soft magnetic material;

a light emitting unit arranged with respect to the magnetic pole in a travel direction of the magnetic head, and emits light with respect to the recording layer;

a distance adjusting unit that adjusts a distance between the magnetic pole and the light emitting unit;

a substantially flat first face and a substantially flat second face on a side opposing the magnetic recording medium, the second face being located at a position separated from the first face in a direction separating from the magnetic recording medium, wherein

each of the magnetic pole, the light emitting unit, and a portion of the distance adjusting unit is arranged on the first face, and

other portion of the distance adjusting unit is arranged on the second face.

7. The magnetic head of claim **6**, further comprising a protective coating covering the second face on a side of the magnetic head opposing the magnetic recording medium, wherein

a face of the protective coating opposing the magnetic recording medium forms a substantially flat face with the first face.

8. A magnetic disk device comprising:

a magnetic recording medium; and

a magnetic head, wherein

the magnetic head is arranged opposite the magnetic recording medium comprising a recording layer, the magnetic head comprising:

a magnetic pole comprising a soft magnetic material;

a light emitting unit arranged with respect to the magnetic pole in a travel direction of the magnetic head, and emits light with respect to the recording layer;

a distance adjusting unit that adjusts a distance between the magnetic pole and the light emitting unit; and

a magnetic pole position control unit having a negative thermal expansion coefficient, and arranged between the magnetic pole and the light emitting unit.

9. The magnetic disk device of claim **8**, further comprising:

a storage unit; and

a controller, wherein

the storage unit stores therein information about a reproduction signal, and

the controller controls the distance adjusting unit based on the information stored in the storage unit to adjust the distance between the magnetic pole and the light emitting unit in the travel direction of the magnetic head.

10. The magnetic disk device of claim **8**, wherein

the light emitting unit is arranged in front of the magnetic pole in the travel direction of the magnetic head, and

the distance adjusting unit is arranged behind the magnetic pole in the travel direction of the magnetic head.

11. A magnetic disk device comprising:

a magnetic recording medium; and

a magnetic head, wherein

the magnetic head is arranged opposite the magnetic recording medium comprising a recording layer, the magnetic head comprising:

a magnetic pole comprising a soft magnetic material;

a light emitting unit arranged with respect to the magnetic pole in a travel direction of the magnetic head, and emits light with respect to the recording layer;

a distance adjusting unit that adjusts a distance between the magnetic pole and the light emitting unit; and

a rigid member arranged in front of the light emitting unit in the travel direction of the magnetic head and configured by a low thermal expansion material.

12. The magnetic disk device of claim **8**, wherein the distance adjusting unit is a piezoelectric element.

13. The magnetic disk device of claim **8**, wherein the light emitting unit generates near-field light based on laser light guided from an outside of the magnetic head.

14. A magnetic disk device comprising:

a magnetic recording medium; and

a magnetic head, wherein

the magnetic head is arranged opposite the magnetic recording medium comprising a recording layer, the magnetic head comprising:

a magnetic pole comprising a soft magnetic material;

a light emitting unit arranged with respect to the magnetic pole in a travel direction of the magnetic head, and emits light with respect to the recording layer;

a distance adjusting unit that adjusts a distance between the magnetic pole and the light emitting unit; and

a substantially flat first face and a substantially flat second face on a side opposing the magnetic recording medium, the second face being located at a position separated from the first face in a direction separating from the magnetic recording medium, wherein

each of the magnetic pole, the light emitting unit, and a portion of the distance adjusting unit is arranged on the first face, and

other portion of the distance adjusting unit is arranged on the second face.

15. The magnetic disk device of claim **14**, further comprising a protective coating covering the second face on a side of the magnetic head opposing the magnetic recording medium, wherein

a face of the protective coating opposing the magnetic recording medium forms a substantially flat face with the first face.

16. The magnetic head of claim **3**, wherein

the light emitting unit is arranged in front of the magnetic pole in the travel direction of the magnetic head, and

the distance adjusting unit is arranged behind the magnetic pole in the travel direction of the magnetic head.

17. The magnetic head of claim **3**, wherein the distance adjusting unit is a piezoelectric element.

18. The magnetic head of claim **3**, wherein the light emitting unit generates near-field light based on laser light guided from an outside of the magnetic head.

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